Au Nanoparticle-based Plasmonic Enhancement of Photocurrent in Gallium Nitride Metal-Semiconductor-Metal (MSM) Ultraviolet Photodetectors

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Abstract

Introduction:
III-nitride semiconductors in general and gallium nitride in particular have recently become increasingly important for optoelectronic applications like LEDs, solar cells and photodetectors [1-3] due to their attractive properties like wide and direct bandgap, high power handling capability and high breakdown field.
GaN as a choice of semiconductor material for UV detectors has gained prominence recently due to advantages like small size and good thermal and chemical stability, and wide bandgap [4]. Among the various photodetector structures, the planar MSM structure has advantages like ease of fabrication, inherently low capacitance and consequently, greater receiver sensitivity as compared to other vertically structured photodetectors.

Experimental Details:
This paper studies the improvement of photocurrent properties obtained by the presence of Au nanoparticles in between the electrode fingers. Nanoplasmonic enhancement of photodetectors by scattering effects has been well known [5,6] and is considered as an effective way of improving the photo current characteristics of a photodetector. There have been studies in literature on the use of plasmonics beyond the visible and into the UV [7] and IR [8-9] part of the spectrum. There has been a study on the use of Ag nanoparticles for the enhancement of UV photoresponse of a GaN MSM photodetector [10]. In that work, the use of Ag had resulted in a slight reduction in Schottky barrier height at the electrode-GaN interface. Ag and Au being the most commonly used plasmonic materials; in this study we explore the use of Au instead of Ag for nanoplasmonic enhancement. Au has a higher electron affinity than Ag and we expect that it will provide better interface characteristics than Ag at the electrode-GaN interface with little or no reduction in scattering efficiency.
Samples used in this work consist of commercially obtained, MOCVD grown, undoped GaN films on c-plance sapphire substrates. This is followed by deposition of a 5nm film of Au on the GaN film using thermal evaporation. This is followed by annealing in nitrogen ambient at 400°C for 30 minutes. SEM images (Figure 1) after annealing confirmed the formation of Au

nanoparticles. The sizes of the particles are found to vary from 40nm to 80nm. This is followed by fabrication of interdigited electrodes to form the MSM photodetector structure (Figure 2). A UV lamp with a spectral range of 300nm to 400nm was used as the source of UV illumination. The dark and photocurrent measurements were made using a probe station and an Agilent B1500A Device Analyzer.

Use of COMSOL Multiphysics®:
The photodetector with plasmonic effects has been modeled using the RF Module along with the newly introduced Semiconductor Module of COMSOL Multiphysics®. COMSOL was chosen for the modeling as it enables us to couple solutions of Maxwell's equations (required to model the plasmonics effects) with the solutions to carrier continuity equations under illumination (required to model the actual photodetector).

Results:
The simulations results agree well with experimental results and we obtain an increase of photocurrent of upto 1.4 times in the presence of the Au nanoparticles (Figure 3)

Reference

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Figures used in the abstract

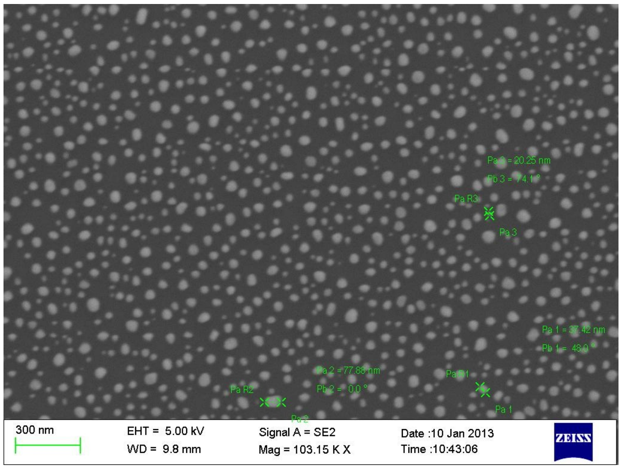

Figure 1: SEM image of Au nanoparticles

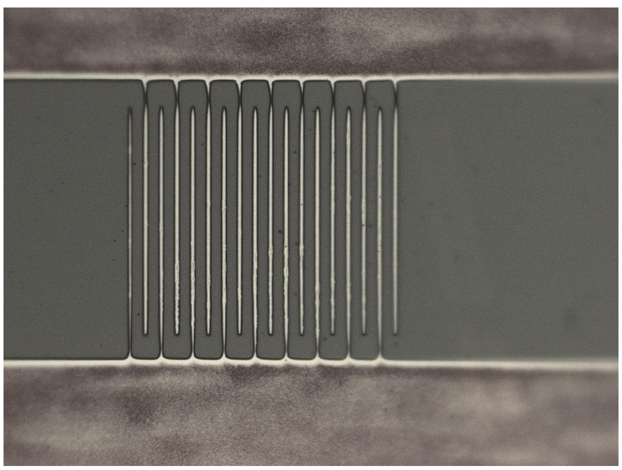

Figure 2: Interdigited electrodes

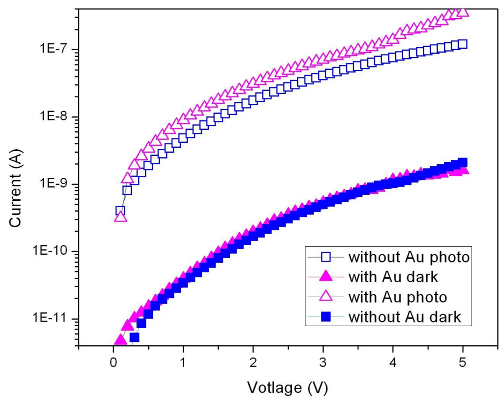

Figure 3: Photodetector dark and photo currents